Summary of Site Risks

Under the NCP, 40 CFR § 300.430, the role of the baseline risk assessment is to address the risk associated with a site in the absence of any remedial action or control, including institutional controls. The baseline assessment is essentially an evaluation of the no-action alterative. (See 55 Fed. Reg. 8666, 8710-8711 (March 8, 1990)). The baseline risk assessment also provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section of the ROD provides a summary of the Site's human health and environmental risks. A baseline human health risk assessment (BHHRA) for the Site was completed in 2004.

Summary of Human Health Risk Assessment

The baseline risk assessment was based on exposure scenarios that estimated the reasonable maximum exposure (RME). The RME is defined as the highest exposure that is reasonably expected to occur at a Site. RMEs are estimated for individual exposure pathways. If a population is exposed by more than one pathway, the combination of exposures across multiple pathways also represents an RME. The intent of the RME is to develop a conservative estimate of exposure that is still within the range of possible exposures.

A four-step process is utilized for assessing Site-related human health risks in the BHHRA:

(1) Identification of Chemicals of Potential Concern (COPCs) – identifies those contaminants that are carried forward through the BHHRA process based on frequency of detection (FOD) and a comparative analysis to EPA human health risk-based screening levels or other appropriate levels (i.e., MCLs);

(2) Exposure Assessment – estimates the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the pathways (e.g,, ingesting contaminated well water) by which humans are potentially exposed;

(3) Toxicity Assessment – determines the types of adverse health effects associated with chemical exposures, and the relationship between magnitude of exposure (dose) and severity of adverse effects (response), and;

(4) Risk Characterization (including the uncertainty analysis) – summarizes and combines outputs of the exposure and toxicity assessments to provide a quantitative assessment of Siterelated risks. With the completion of this four-step risk assessment process, those exposure pathways and chemicals of concern (COCs) found to pose actual or potential threats to human health at the Site are identified for remedial action.

Summary of Ecological Risk Assessment

Identification of Chemicals of Concern

EPA defines COPCs as those chemicals that pose an excess lifetime carcinogenic risk to human health greater than 1 cancer case in 1,000,000 individuals (1×10^{-6}), have a noncarcinogenic hazard index (HI) greater than (>)1 or are found in Site ground water at concentrations that exceed Maximum Contaminant Limits (MCLs).

IDENTIFICATION OF POTENTIAL CHEMICALS OF CONCERN

EPA guidance (EPA, 1989) recommends considering several steps to eliminate compounds from further evaluation and, as such, this section describes the process used to reduce the list of chemicals evaluated in the BHHRA. Compounds were eliminated from further consideration if: 1) they were detected infrequently in a given media (i.e., in less than five percent of the samples); 2) they were measured at similar concentrations in blank samples; 3) they were measured at similar concentrations in background samples; or 4) they were detected at a high concentration (above one tenth of the screening value discussed below).

If a compound was detected in less than five percent of the samples, the compound was eliminated from further evaluation for that media. This step was only considered in media where twenty or more samples were collected and if that compound was not present in another media. ~~The lab did not report any blank contamination issues with the data so no compounds were eliminated based on this criterion.~~

The data for soil, groundwater, surface water, and sediment are summarized in Tables 1 through 15. ~~T~~These tables show the frequency of detection, minimum, maximum, and average concentration for each COI. The 95% upper confidence limit (95% UCL) on the mean concentration was calculated as described in Section 3. ~~Appendix A provides the statistical calculations for these data.~~

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Concentration-Toxicity Screen

A "concentration-toxicity screen" step, as recommended by EPA (EPA, 1989), was conducted to limit the number of chemicals that were included in a quantitative risk assessment while also ensuring that all chemicals that might contribute significantly to the overall risk were addressed. The screening values used were $1/10^{th}$ of the human health criteria, which were the lower of the EPA or TCEQ values as presented in the NEDR (PBW, 2009) for soil, surface water, and sediment. Because there are no readily available screening levels appropriate for the complete groundwater pathway at the Site, all chemicals of interest for groundwater media were quantitatively evaluated in the risk assessment. A similar screen was conducted for media collected at the background areas, but this was done merely for comparative purposes. Risks associated with background concentrations were not calculated in the BHHRA.

Exposure and risk calculations were not estimated for the surface water pathway in the Intracoastal Waterway and Wetlands Area because none of the measured maximum COI concentrations exceeded 1/10th of their respective TCEQ's contact recreation Protection Concentration Level (PCL). These PCLs were developed for a child exposure scenario for noncarcinogenic compounds, and an age-adjusted scenario for carcinogenic compounds. The PCL is based on incidental ingestion and dermal contact of surface water while swimming for three hours, 39 times per year. It is believed that this is a bounding estimate for the Intracoastal Waterway, surface water north of Marlin Ave., and the ponds north of Marlin Ave. since none of these surface water bodies are very favorable for swimming and true exposure is likely to be much less than the scenario described by TRRP's contact recreation PCL. All surface water concentrations were well below 1/10th of the PCL for the Intracoastal Waterway and wetlands area surface water. Maximum measured concentrations of arsenic and thallium in the pond samples exceeded 1/10th of their respective PCL but did not exceed the PCL and, therefore, neither were retained for further evaluation. Although TCEQ does not provide a PCL for iron, one was calculated using the contact recreation assumptions (TCEQ, 2006). Measured concentrations of iron in surface water were well below the calculated contact recreation PCL of 2,800 mg/L. Therefore, it was concluded that chemical concentrations of PCOCs in surface water samples from the Intracoastal Waterway near the Site, surface water in the North Area wetlands, and surface water in the North Area ponds do not pose an unacceptable health risk and chemical concentrations in these media were not evaluated further in the BHHRA.

Comparison to the Background Areas

To help provide an understanding of what COIs and concentrations are considered to be Site-related, a background evaluation was conducted (as described in the Work Plan (PBW, 2006a)) that included: 1) soil samples from ten off-site locations; 2) sediment samples from nine off-site locations in the Intracoastal Waterway; and 3) surface water samples within four off-site "zones" in the Intracoastal Waterway. This information was used to characterize Site conditions in the NEDR (PBW, 2009).

The soil background data were compared to soil from the South Area and North Areas of the Site, as well as sediments from the North wetland and the North Area ponds. As described in the NEDR (PBW, 2009), based on similarities in composition and condition between background soil and sediments of the North wetlands area, this comparison was appropriate. Sediment and surface water data for the Intracoastal Waterway samples were compared to sediment and surface water data collected in the Intracoastal Waterway background location.

Comparisons between Site sampling data and Site-specific background data were conducted for all inorganic compounds measured regardless if they exceeded the concentration-toxicity screen~~. The background comparisons were performed in accordance with EPA's *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA, 2002d). .~~ ~~Distribution testing was conducted to estimate 95% UCLs and the summary statistics were used to perform comparison of the means analyses. The output of these background statistical comparison tests is provided in Appendix B.~~ Table 16 summarizes the results of the testing and indicates whether the Site data were found to be statistically different than the background data.

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~~In several instances (e.g., lithium in South Area soil; barium in North Area wetlands sediment), statistical differences between the two data sets were due to higher concentrations in the background population. If there was not Site-specific background data for a COI and it was measured in excess of 1/10th of the screening level, the COI was retained for further evaluation in the BHHRA (e.g., iron). COIs shown to be statistically different (and higher) when compared to background data were also retained for quantitative evaluation in the BHHRA. The PCOCs carried through the BHHRA for soil, surface water, and sediment are listed in risk assessment tables at the end of this document.~~

~~A statistical comparison between Site surface water and background surface water could not be conducted given the small size of both data sets. Visual inspection of the data indicates that there is no consistent observable difference between the data sets for the COIs. It should be noted, however, that all COIs in surface water were screened out during the toxicity-concentration step and are not evaluated further in the BHHRA.~~

~~B~~Background groundwater data were not collected as part of the RI. Therefore, all COIs detected in Zone A groundwater, as shown in tables for the South Area and North Area, respectively, were evaluated quantitatively in the BHHRA and are discussed in greater detail in the following sections.

1.0 EXPOSURE ASSESSMENT

The exposure assessment estimates the extent of human contact with PCOCs by characterizing potentially exposed populations (i.e., receptors), identifying actual or potential routes of exposure, and quantifying the intake (or dose) of human exposure. The exposure assessment also identifies possible exposure pathways that are appropriate for each potential receptor and exposure scenario and considers the source of contamination and fate and transport properties of the compound and surrounding environment. An exposure pathway typically includes the following elements:

- A source of contaminant and mechanism of contaminant release;
- An environmental retention or transport medium (e.g., air, groundwater, etc.);
- A point of contact with the medium (i.e., receptor or potentially exposed population); and
- A route of human intake (e.g., inhalation, ingestion, etc.).

Each of these elements must generally be present for an exposure pathway to be complete, although it is not necessary that environmental transport occurs when assessing exposure from direct contact. Exposure was evaluated for both current and potential future receptors to allow for evaluation of long-term risk management options.

POTENTIAL EXPOSURE PATHWAY EVALUATION

The identification of potentially exposed populations (also called receptors) possibly at risk from exposure to PCOCs at the Site is dependent on current and future land uses.
The Site consists of approximately 40 acres within the 100-year coastal floodplain along the north bank of the Intracoastal Waterway between Oyster Creek to the east and the Old Brazos River Channel to the west. Approximately 78 people live within the one square mile area surrounding the Site (EPA, 2005a). Approximately 3,392 people live within 50 square miles of the Site (EPA, 2005a). There are no schools, nursing homes, or other sensitive subpopulations within a mile of the Site. Residential areas are located south of Marlin Avenue, approximately 300 feet west of the Site, and 1,000 feet east of the Site.

Land Use and Pathway Evaluation

Historically, the South Area of the Site was used as a barge cleaning and maintenance facility. The Site currently is unused but it is anticipated that the South Area will be used for commercial/industrial purposes in the future. The South Area includes approximately 20 acres of upland that was created from dredged material from the Intracoastal Waterway. To the west of and directly adjacent to the Site is an unused lot that was formerly a commercial marina. West of that lot, beyond a second vacant lot, is a residential development with access to the Intracoastal Waterway. An active commercial operation is located east of the South Area.

The North Area of the Site contains closed surface impoundments (closed in 1982) and is, for the most part, unused. Some of the North Area is upland created from dredge spoil, but most of this area is considered wetlands and the wetlands area has never consistently been used. According to the National Wetlands Inventory map for the Freeport Quadrangle, the wetlands on the north of the Site are estuarine, intertidal, emergent, persistent, and irregularly flooded. The upland area of the North Area has been used as a parking lot. Future land use at the North Area is limited given that much of it is considered wetlands and most of the upland part of the North Area consists of the closed former surface impoundments.

Groundwater Use and Pathway Evaluation

Because of high total dissolved solids in Zone A, B, and C groundwater at the Site, the groundwater ingestion and use pathway is incomplete for these three units. Also, as noted previously, restrictive covenants prohibiting groundwater use have been filed for the Site. Based on Site potentiometric and analytical data presented in the NEDR (PBW, 2009), impacted groundwater does not affect surface water at the Site. Thus, the only complete exposure pathway is the volatilization to indoor and outdoor air pathway in areas above impacted groundwater. A restrictive covenant requiring any building design to preclude vapor intrusion has been filed for Lots 55, 56, and 57 where VOC concentrations were measured in relatively high concentrations in Zone A groundwater. Nevertheless, this pathway was conservatively evaluated in the BHHRA.

Surface Water Use and Pathway Evaluation

The Intracoastal Waterway supports barge traffic and other activities. It is one of the main arteries for shipping goods from Freeport's deep-water port to destinations along the Texas Coast and beyond.

Fishing boats also use the Intracoastal Waterway to gain access to the fishing grounds in the Gulf of Mexico and the shorelines, tributaries, and marshes of the many Texas Bays. The area near the Site is regularly dredged. The nearby residential areas have canal access to the Intracoastal Waterway.

As noted previously, impacted groundwater does not discharge to surface water at the Site. However, surface water data were collected for the Intracoastal Waterway, as well as surface waters contained in the wetlands and ponds on the North Area to evaluate the potential for contaminants in surface soils to be released to surface water via overland surface runoff. A contact recreation scenario was included in the risk assessment to evaluate risks associated with occasional swimming and wading in surface water of the Intracoastal Waterway, and surface waters on the North Area. Based on the screening evaluation presented in Section 2.2.1, the surface water pathway was eliminated from further consideration since it does not pose an adverse human health risk.

Fish and Shellfish Resources and Pathway Evaluation

As mentioned previously, fishing and crabbing are reported to occur in waters of the Intracoastal Waterway in the general vicinity of the Site. Based on the analytical results for the Intracoastal Waterway sediment samples and in accordance with Section 5.6.8 of the Work Plan, fish tissue samples were collected from four Site zones and one background area within the Intracoastal Waterway. Red drum (*Sciaenops ocellatus*) (6 samples), spotted seatrout (*Cynoscion nebulosus*) (9 samples), southern flounder (*Paralichthys lethostigma*) (9 samples), and blue crab (*Callinectes sapidus*) (9 samples) samples were collected from the Site for laboratory analysis. Samples of these species were also collected from the background area and were archived.

The Site fish tissue samples (fillet samples for finfish, edible tissue for crabs) were analyzed for 12 COIs, based on Intracoastal Waterway sediment data, in accordance with EPA's November 14, 2006 letter. The only COIs with concentrations measured above sample detection limits in any of the 33 samples were silver (detected in four samples), benzo(b)fluoranthene (detected in two samples), and 4,4'-DDE (detected in two samples). The fish tissue data were used to calculate potential risks associated with exposure to Site COIs via the fish ingestion pathway to recreational anglers fishing at the Site, or their families. This risk assessment (presented in a March 20, 2007 letter to EPA) concluded that the fish ingestion pathway does not pose a human health threat (PBW, 2007). That conclusion was subsequently approved in a June 29, 2007 letter from EPA.

In addition, shellfish harvesting is banned by the Texas Department of Health Services, Seafood Safety Division in all waterbodies from an area about two miles east of the Site, to well beyond the Brazos River inlet, about 7 miles west of the Site. The ban has been enacted because of poor conditions and water quality. It should be noted, however, that risk from shellfish consumption harvested from the area if allowed would most likely not pose a human health risk, since exposure would be similar if not the same as for the fish and crab ingestion pathway.

For the reasons described above, the fish/shellfish pathways were not evaluated further in this risk assessment. The pathway was included in the Conceptual Site Model as discussed in Section 3.3 below.

POTENTIALLY EXPOSED POPULATIONS

Based on current and reasonable future land use, potentially exposed populations for the South Area include: 1) future commercial/industrial workers and 2) future construction workers at the Site. A youth trespasser was also evaluated since, although the South Area perimeter is fenced, this area could still be accessed by a trespasser via the Intracoastal Waterway. Soil is the primary media of concern for these receptors. A future indoor air exposure pathway was evaluated for the commercial/industrial worker since volatile organic compounds (VOCs) were detected in Zone A groundwater. Additionally, a contact recreation scenario was assessed for surface water and sediment in the Intracoastal Waterway to represent a hypothetical person who occasionally contacts these media while swimming, wading, or participating in other recreational activities. Potential impacts from fugitive dust generation and VOC emissions, and subsequent exposure to nearby residents were also considered in the BHHRA.

Based on current and reasonable future land use, potentially exposed populations include future commercial/industrial workers and future construction workers at the Site. A youth trespasser was also evaluated since this area is not fenced. Soil is the primary media of concern for these receptors. A future indoor air exposure pathway was evaluated for the commercial/industrial worker since VOCs were detected in Zone A groundwater. Additionally, a contact recreation scenario was assessed for surface water and sediment in the wetlands and ponds of the North Area to represent a hypothetical receptor who occasionally contacts these media while wading, birding, or participating in other recreational activities. Given the frequently saturated nature of the wetlands sediment and the abundant vegetation on the

uplands portion of the North Area, fugitive dust generation and VOC emissions, and off-site impacts were not considered.

While exposure might occur at the background locations, exposure and potential risks for background areas were not evaluated in the BHHRA.

CONCEPTUAL SITE MODELS AND POTENTIALLY COMPLETE EXPOSURE PATHWAYS

A conceptual site model (CSM) identifies exposure pathways for potentially complete pathways at the Site and describes the process or mechanism by which human receptors may reasonably come into contact with Site-related constituents. A CSM was developed as part of the Work Plan (PBW, 2006a) to focus the data collection activities of the RI so that analytical data could support a risk-based analysis. Figures 4 and 5 of the BHHRA provide revised CSMs for the South and North Areas, respectively, which were refined to reflect current information about the Site. These revised CSMs were used to develop the quantitative exposure assessment of the BHHRA. Complete pathways are indicated with a bold line and check in the potential receptors column. Incomplete pathways are denoted with an "X" and a footnote indicating why the pathway is incomplete.

At the South Area, PCOCs were potentially released from historical Potential Source Areas (PSAs) to the soil and may have migrated to groundwater via leaching through the soil column, and to surface water in the Intracoastal Waterway via overland surface runoff. Once in surface water, some compounds tend to stay dissolved in the water whereas some tend to partition to sediment. Volatilization and fugitive dust generation may have caused PCOCs in soil to migrate within the Site or off-site. Exposure to on-site receptors may also occur directly from contact to the soil. However, based on PCOC data for surface soil samples collected on Lots 19 and 20 directly west of the Site (see Section 2.4.2 of the NEDR for detailed discussion of these data (PBW, 2009)), it does not appear that significant entrainment and subsequent deposition of particulates occurred at the Site or at off-site locations. Once in groundwater, VOCs may migrate with the groundwater and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

At the North Area, PCOCs were potentially released from historical PSAs to the soil and/or may have migrated to groundwater. PCOCs may have also migrated from soil to surface water and sediments in the

nearby wetlands area via overland surface runoff. Because of the high moisture content and the vegetated nature of the limited surface soils in the North Area, fugitive dust generation is not considered a significant transport pathway for PCOC migration. Once in groundwater, VOCs may migrate with the groundwater and/or volatilize through the soil pore space and be emitted into outdoor or indoor air.

It was assumed, as part of the risk assessment, that these media were potentially contacted by the various hypothetical receptors possibly at the Site and, as such, these exposure pathways were potentially complete. The remainder of this section describes how exposure was quantified for each of these complete exposure pathways.

QUANTIFICATION OF EXPOSURE

In keeping with EPA guidance (EPA, 1992c), the goal of the exposure assessment was to provide a reasonable, high-end (i.e., conservative) estimate of exposure that focuses on potential exposures in the actual population. This concept is termed the reasonable maximum exposure (RME) approach. This should not be confused with: (1) a worst-case scenario which refers to a combination of events and conditions such that, taken together, produces the highest conceivable exposure; or (2) a bounding estimate that purposefully overestimates exposure (EPA, 1992c). Thus, in accordance with EPA guidance, site-specific exposure assumptions and parameters were used when available and, when not available, assumptions were deliberately chosen to represent a high-end RME estimate (EPA, 1989). A central tendency or average scenario was also evaluated to provide a range of exposures.

Chemical exposure is quantified by the calculation of an intake, or dose, that is normalized to body weight and exposure time of the receptor. A dose is calculated by combining assumptions regarding contact rate (intake amount and time, frequency and duration of exposure) to a contaminated medium with representative chemical exposure point concentrations for the medium of concern at the point of contact. Receptors are chosen based on their exposure patterns that may put them at risk or at a higher risk than other individuals. Intake assumptions, in general, were based on central tendency or RME assumptions determined by EPA (1989; 1991a), or were based on information obtained from site-specific studies. Reasonable maximum exposure scenarios use a combination of assumptions, such as average values for physical characteristics of the receptors (body weight and corresponding body surface area), UCL values (values at the 90 or 95 percentile of the distribution) for contact rate, and UCL on the mean

~~(95 percent UCL)~~ for the exposure point concentrations. The combination of these factors is assumed to provide an upper-bound estimate of exposure and risk to that particular receptor.

The intake or dose of a particular compound by a receptor is quantified with the generic equation below (EPA, 1989):

$$I = \frac{C \times CR \times EFD}{BW} \times \frac{1}{AT} \qquad \text{(Equation 1)}$$

where:

I	=	the compound intake or dose (mg/Kg BW-day);
C	=	the compound concentration (mg/Kg or mg/L);
CR	=	contact rate or the amount of contaminated medium contacted per event (L/day or mg/day);
EFD	=	the frequency (days/year) and duration (number of years) of exposure days;
BW	=	the average body weight of the receptor (Kg); and
AT	=	averaging time of the exposure (days); for noncarcinogens, AT equals (ED) x (365 day/year); for carcinogens, AT equals (70 years over a lifetime) x (365 day/year).

This equation calculates an intake that is normalized over the body weight of the individual and the time of the exposure. Because the intake or dose is combined with quantitative indices of toxicity (chemical-specific dose-response information such as reference doses (RfDs) for noncarcinogenic compounds or cancer slope factors (CSFs) for carcinogenic compounds, which is discussed further in Section 4.0) to give a measure of potential risk, the intake or dose must be calculated in a manner that is compatible with the quantitative dose-response information for chemical constituents evaluated in the analysis. Two different types of health effects are considered in this analysis: 1) carcinogenic effects and 2) noncarcinogenic effects (either chronic or subchronic, depending on the receptor's exposure).

For carcinogenic effects, the relevant intake is the total cumulative intake averaged over a lifetime because the quantitative dose-response function for carcinogens is based on the assumption that cancer results from chronic, lifetime exposures to carcinogenic agents. This intake or dose is then averaged over a lifetime to provide an estimate of intake or dose to carcinogens as (mg/Kg-day), which is expressed as a lifetime average daily dose (LADD). Thus, for potentially carcinogenic compounds, the averaging time (AT) is equal to 70 years (EPA, 1989).

Noncarcinogenic effects are evaluated for chronic, subchronic, or acute exposures by receptors to systemic or reproductive toxicants. For noncarcinogenic effects, the relevant intake or dose is based on the daily intake averaged over the exposure period of concern. As defined in EPA guidance (EPA, 1989),

an exposure period for toxicity can be either acute (exposure occurring from one event or over one day), subchronic (cumulative exposures occurring from two weeks up to seven years), or chronic (cumulative exposure over seven years to a lifetime in duration). The quantitative dose-response function for noncarcinogenic effects (chronic and subchronic) is based on the assumption that effects occur once a threshold dose is attained from repeated exposure. Therefore, the intake or dose for noncarcinogenic risk assessment is based on an average daily dose (ADD) that is averaged over the duration of exposure. The averaging time for assessing noncarcinogenic effects is equal to the exposure duration for the receptor. In the BHHRA, exposure was assumed to be chronic for all receptors even though some exposures described in this report were intermittent or less than chronic duration.

Estimating the Exposure Point Concentration

The general procedure that is recommended by EPA to estimate a 95% UCL (EPA, 2002b) was used as the EPC to represent the upper end of exposure. EPA's ProUCL Version 4 program (EPA, 2007) was used to analyze dataset distribution and calculate average and 95% UCL concentrations. ProUCL calculates various estimates of the 95% UCL of the mean, and then makes a recommendation on which one should be selected as the best UCL estimate. If the 95% UCL was greater than the maximum detected concentration, the maximum measured concentration was used as the exposure point concentration (EPA, 2002b).

Appendix A provides the ProUCL output when there were sufficient samples to run statistics (soil and sediment). It should be noted that when evaluating exposure from fugitive dust generation, the exposure point concentration was based on surface soil data because it is unlikely that deeper soils (i.e., soils below a depth of 0.5 ft) are transported as wind-borne dust. One-half of the SDL was used for sample measurements below the SDL. There were not enough pond sediment or surface water samples for statistical calculations so average and maximum measured concentrations were used in the evaluation for these media.

Both averages and 95% UCLs were used in the BHHRA to provide a range of exposure point concentrations and are summarized in Tables 1 through 15. The dose estimates using the 95% UCL EPC were considered to represent reasonable maximum exposure (RME). The average was used to represent the average or central tendency exposure.

Quantifying Intake

To quantify potential exposures associated with the pathways of potential concern, Equation 1 is modified according to the specific exposure routes and intake assumptions.

Incidental Ingestion of Soil. The intake or dose for the incidental ingestion pathway from soil is calculated based on the following equation (EPA, 1989):

$$ADD_{ing} = \frac{Conc_{soil} \times IR \times FI \times AAF \times EF \times ED \times CF}{BW \times AT}$$

(Equation 2)

where:

ADD_{ing}	=	average daily intake of compound via ingestion of soil (mg/Kg BW-day);
$Conc_{soil}$	=	exposure concentration in soil (mg/Kg);
IR	=	ingestion rate (mg soil/day);
FI	=	fraction ingested (unitless);
AAF	=	absorption adjustment factor (fraction absorbed);
EF	=	exposure frequency (days/year);
ED	=	exposure duration (years);
CF	=	conversion factor (10^{-6} Kg/mg);
BW	=	body weight (Kg); and
AT	=	averaging time (days).

The exposure concentration in the soil ($Conc_{soil}$) is the concentration of a PCOC at the point of contact. Exposure point concentrations represent random exposure over the exposure unit and were discussed in greater detail in the Section 3.4.1. The ingestion rate (IR) is the amount of soil incidentally ingested per day or event. For soil, the incidental intake values vary according to the receptor and the specific activities or exposure patterns that the receptor is engaged in at the Site.

The fraction ingested (FI) relates to the fraction of soil that is contacted daily from the contaminated area. This is highly dependent on the different activities that an individual is engaged in and the number of hours (fraction of time) spent in the contaminated portions of the site (EPA, 1989). The fraction ingested was conservatively assumed to be 100 percent. The absorption adjustment factor (AAF) is used in the ingestion pathway to account for differences in relative absorption for the chemical from the test vehicle versus the exposure medium (i.e., soil) and was assumed to be 1.0 unless compound-specific data were

available to suggest otherwise. (The test vehicle is the material (e.g., soil, food, or solvent) in which the chemical was administered in the toxicity study.) Body weight (BW) varies according to the age range of the receptor. Adult receptors are assumed to weigh 70 kilograms (Kg), which corresponds to the 50^{th} percentile value for all adults, as recommended by EPA (1989). For receptors other than adults, body weight is dependent on the age of the receptor and is calculated as the time-weighted average body weight using values reported by the *Exposure Factors Handbook* (EPA, 1997a). The exposure frequency (EF) and duration (ED) of the event is based on the particular exposure pattern and activity related to the receptor (EPA, 1997a). The averaging time is 70 years for carcinogenic effects, and for noncarcinogenic effects depends on the frequency and duration of exposure for the particular receptor (EPA, 1989; 1991a).

Dermal Contact with Soil. When calculating intake via dermal contact with soil or sediment, Equation 1 is modified slightly to account for skin surface area, soil-to-skin adherence factors, and chemical-specific absorption factors. An intake or dose is quantified from dermal contact with the equation (EPA, 1989):

$$ADD_{der} = \frac{Conc_{soil} \times SA \times AF \times AAF \times EF \times ED \times CF}{BW \times AT} \qquad \text{(Equation 3)}$$

where:

ADD_{der}	=	average daily dose from dermal contact with chemical in soil (mg/Kg-day);
$Conc_{soil}$	=	exposure concentration in soil (mg/Kg);
SA	=	skin surface area available for direct dermal contact (cm^2/event);
AF	=	soil/sediment to skin adherence factor (mg/cm^2);
AAF	=	absorption adjustment factor (unitless)
EF	=	exposure frequency (days or events/year);
ED	=	exposure duration (years)
CF	=	conversion factor (10^{-6} Kg/mg);
BW	=	body weight (Kg); and
AT	=	averaging time (days).

The exposed skin surface area (SA) is the area or portion of the body exposed for dermal contact. As with many exposure variables, surface area depends on the age and exposure pattern that the receptor is engaged in that relate to repeated or average exposure. Surface area can be predicted based on factors such as activity and types of clothing. Typical exposures via dermal contact for most receptors are generally limited to certain parts of the body (e.g., hands, forearms, head, and neck) since clothing tends to significantly reduce the potential for direct contact with soil (Kissel, 1995). The soil adherence factor (AF) is the density of soil adhering to the exposed fraction of the body. The adherence factor is highly dependent on the specific activity of the receptor as well as physical properties of the soil (e.g., moisture content, textural class, and organic carbon content) (Kissel et al., 1996). The AAF accounts for the relative absorbance of a chemical between dermal exposure from the environmental medium and oral

exposure in the critical toxicity study, which was used to derive the dose-response information for that chemical. Therefore, the AAF is highly chemical-specific and, unless otherwise noted, was assumed to be 1.0. Factors such as body weight, exposure frequency, exposure duration, and averaging time are similar to that discussed above for incidental ingestion.

Inhalation of Volatiles and Fugitive Dusts. An intake or dose from inhalation of vapors or particles emitted from the Site is calculated by modifying Equation 1 to account for the volatilization and/or particulate emission factor and the difference in methodology when evaluating air impacts (i.e., dose was not calculated, but rather an effective air concentration that the receptor may be exposed to was calculated). An effective air concentration was generally calculated using the following equation:

$$EAC = Conc_{soil} \times VF \times EF \times ED / AT \qquad \text{(Equation 4)}$$

where:

EAC	=	effective air concentration (mg/m^3);
$Conc_{soil}$	=	exposure point concentration in soil (mg/Kg);
VF	=	volatilization factor (mg/m^3-air/Kg-soil) and/or particulate emission factor:
EF	=	exposure frequency; describes how often exposure occurs (days/year);
ED	=	exposure duration; describes how long exposure occurs (years); and
AT	=	averaging time; period over which exposure is averaged (days).

A risk assessment from inhalation of volatiles and dusts is different from the quantification of potential risks from dermal contact or incidental ingestion. Risks from inhalation exposure are based on a comparison of a measured or calculated air concentration (effective air concentration) to a risk-based acceptable air concentration, either a reference concentration (RfC) or an inhalation unit risk (IUR) value. Where monitoring data do not exist, an exposure point concentration in air can be calculated based on a volatilization model and/or particulate emissions factor and the exposure point concentration in soil. Surface soil data were used when estimating the air concentration for particulate dust generation.

Exposure Assumptions and Intake Calculations

The exposure assumptions are provided in Tables 19, 20, 21, and 22 for the industrial worker, construction worker, youth trespasser, and contact recreation receptors, respectively. References for the various assumptions are provided in the tables and citations are listed in Section 8.0. Appendix C

provides the detailed spreadsheets for the intake calculations for the different receptors for the South and North Areas of the Site.

Instead of employing a highly uncertain particulate emission factor and fugitive dust dispersion model to evaluate off-site exposure, potential risks from South Area soil to the nearby off-site residential receptor were conservatively evaluated using the residential PCL for 30-acre source area for the soil-to-air pathway (inhalation of volatiles and particulates). Maximum measured concentrations of PCOCs in South Area soils were compared to their respective PCLs as shown in Table 23 and 24. Based on this comparison, it is unlikely that PCOCs contained in soil at the South Area of the Site were emitted off-site at deleterious concentrations.

~~1.1.1~~ Vapor Intrusion Pathway for Future On-Site Worker Scenarios

Except for an aboveground storage tank (AST) tank farm, a dry dock, and a former transformer shed, there are currently no structures present on the South or North Areas at the Site. However, future development of the area may result in construction of buildings at the Site. In the event that permanent and enclosed structures are built on-Site in the future, the Johnson and Ettinger Vapor Intrusion Model (J&E VIM) (EPA, 2002a) was used to assess the potential migration of volatile chemicals from groundwater into the breathing space of an overlying building. Exposure estimates are calculated in the model using default exposure parameters for an industrial worker similar to those provided in Table 19 and site-specific soil and hydrogeologic properties. While a construction worker could also be exposed to VOCs migrating from groundwater to outdoor air, that exposure and risk scenario was not calculated separately since it is likely to be less than the industrial worker's exposure under the indoor air scenario since there would be greater dispersion and mixing in the ambient outdoor air that a construction worker would encounter (no dispersion and mixing is assumed with the J&E VIM), and because the construction worker's exposure frequency and duration is less than the industrial worker's.

The input parameters used to run the J&E VIM Version 3.1 followed EPA guidance on the subject and recommended values (EPA, 2002a) that are available on-line at www.epa.gov/oswer/riskassessment/airmodel/johnson_ettinger.htm . Site-specific input variables used in the model are described below. The model was only run for those compounds that are considered volatile since non-volatile compounds would not migrate from the groundwater to the overlying soil pore space and to ambient air via this pathway. As noted previously, a restrictive covenant is currently in place for

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Lots 55, 56, and 57 and requires any building design to preclude vapor intrusion. Thus, this evaluation represents a conservative assessment of the vapor intrusion pathway for these lots.

The site-specific variables used in the J&E model were determined from information gathered during previous Site investigation and presented in the NEDR (PBW, 2009). Depth below grade to the bottom of a hypothetical enclosed space floor was assumed to be 15 cm, or the thickness of a typical slab (basement construction was not considered due to the geographic location of the Site). Depth below grade to the water table was conservatively estimated to be 5 feet (152 cm) based on water gauging data from both North and South Area monitoring wells. Clay (USCS code CL) was selected as the soil type directly above the water table, which is the dominant soil type in shallow soils at both the North and South Areas as indicated on the boring logs provided in NEDR (PBW, 2009). The average soil/groundwater temperature used in the model was 25° C based on the geographical location of the site and regional climatic conditions.

Both average and RME EPCs were used in the calculations to provide a range of exposure and potential risks. These values are listed in Tables 25 and 26.

TOXICITY ASSESSMENT

The toxicity assessment provides a description of the relationship between a dose of a chemical and the anticipated incidence of an adverse health effect (Preuss and Ehrlich, 1987 and EPA, 1989). The purpose of the toxicity assessment is to provide a quantitative estimate of the inherent toxicity of PCOCs to incorporate into the risk characterization. Toxicity values are derived from the quantitative dose response association and are correlated with the quantitative exposure assessment in the risk characterization.

For risk assessment purposes, toxic constituent effects are separated into two categories of toxicity: carcinogenic effects and noncarcinogenic effects. This division relates to the EPA policy that the mechanisms of action for these endpoints differ. Generally, the EPA has required that potentially carcinogenic chemicals be treated as if minimum threshold doses do not exist (EPA, 1986), whereas noncarcinogenic effects are recognized to have a threshold below which toxicity is unlikely.

EXPOSURE ROUTE-SPECIFIC TOXICITY CRITERIA

In deriving toxicity criteria, EPA methodologies consider the route of administration (or exposure) of the test chemical in toxicity or epidemiological studies. Typically oral RfDs and oral CSFs are derived from toxicity studies with oral administration or exposure route, and RfCs or inhalation unit risks are derived from inhalation toxicity studies. While one could attempt to extrapolate an inhalation toxicity criterion to the oral pathway or visa versa, this practice is not recommended because there can be a great deal of uncertainty introduced (EPA, 1989). Therefore, in the BHHRA, oral RfDs were not extrapolated to provide toxicity values for inhalation pathways. Quantitative risk evaluation of the inhalation exposure pathways was conducted only for those chemicals that have reference toxicity values specifically from inhalation administration.

On the other hand, EPA has not derived specific toxicity criteria for the dermal exposure pathway. This presents a complication because oral and inhalation toxicity criteria are based on administered dose and not absorbed dose while dermal exposure pathways consider the absorbed dose (i.e., how much of the chemical in soil or water crosses the skin barrier and is absorbed by the body). Per EPA (1989), the oral RfD or oral CSF can be applied in evaluation of the dermal exposure pathway following adjustment of the oral toxicity criteria for gastrointestinal absorbance. In later guidance (EPA, 2004b), EPA recommends adjusting oral toxicity criteria by gastrointestinal absorbance factors if gastrointestinal absorbance of the chemical in the vehicle of administration in the critical study is less than 50 percent. Generally, organic chemicals are assumed to be relatively bioavailable in oral and gavage toxicity studies and, thus, the administered dose is likely to be similar to absorbed dose. Therefore, no adjustment of oral toxicity criteria is recommended for organic PCOCs (EPA, 2004b). EPA recommends adjusting oral toxicity criteria for a number of inorganic constituents based on the possibility of low gastrointestinal absorbance in the critical study as shown in Exhibit 4-1 of the associated guidance (EPA, 2004b). It should be noted that none of the PCOCs quantitatively evaluated in the BHHRA are recommended for the adjustment described above.

CARCINOGENIC EFFECTS

Potential carcinogenic effects resulting from human exposure to constituents are estimated quantitatively using cancer slope factors (CSFs), which represent the theoretical increased risk per milligram of constituent intake/kilogram body weight/day $(mg/Kg\text{-}day)^{-1}$ or unit risks, which are the theoretical increased risks per exposure concentration. CSFs or unit risks are typically derived for "known or probable" human carcinogens. CSFs or unit risks are used to estimate a theoretical upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular lifetime daily dose of

a potential carcinogen. Constituents that are believed to be carcinogenic may also have non-cancer effects. Potential health risks for these constituents are evaluated for both cancer and other types of effects as described below.

NONCARCINOGENIC EFFECTS

Unlike carcinogenic effects, it is widely accepted that noncarcinogenic biological effects of chemical substances occur only after a threshold dose is achieved (Klaassen et al., 2007). This threshold concept of noncarcinogenic effects assumes that a range of exposures up to some defined threshold can be tolerated without appreciable risk of harm. Adverse effects may be minimized at concentrations below the threshold by pharmacokinetic processes, such as decreased absorption, distribution to non-target organs, metabolism to less toxic chemical forms, and excretion (Klaassen et al., 2007).

Reference dose (RfD) values and reference concentrations (RfCs) are developed by the EPA RfD Work Group on the basis of a wide array of noncarcinogenic health effects. The RfD and RfC are estimates of the daily maximum level of exposure to human populations (including sensitive subpopulations) that are likely to be without an appreciable risk of deleterious effects during a lifetime (EPA, 1989). RfDs are expressed in units of daily dose (mg/Kg-day) while RfCs are expressed as an air concentration (mg/m^3). Both incorporate uncertainty factors to account for limitation in the quality or quantity of available data.

SOURCES OF TOXICITY CRITERIA

There are a variety of toxicity databases that regulatory agencies rely on for the purposes of quantifying the toxicity of chemicals in the environment. Per EPA (1989 and 2003), the primary source (i.e., "Tier 1") for toxicity information in the risk assessment should be EPA's Integrated Risk Information System (IRIS) (EPA, 2008). According to a recent OSWER directive (EPA, 2003), that revises the human health toxicity value hierarchy, if RfDs for noncarcinogenic compounds and CSFs for possible carcinogens are not available in IRIS, the "Tier 2" toxicity resource is the EPA's database of Provisional Peer Reviewed Toxicity Values for Superfund (PPRTV). The "Tier 3" resources that can be consulted if IRIS and PPRTV databases lack relevant toxicity criteria include the Health Effects Assessment Summary Tables (EPA, 1997b) and the Centers for Disease Control's Agency for Toxic Substances and Disease Registry (ATSDR) Minimal Risk Levels (MRLs).

The toxicity criteria used in the BHHRA are provided in Appendix D, along with the risk calculations. All toxicity values were obtained from EPA's IRIS on-line database, as accessed during December 2008.

2.0 RISK CHARACTERIZATION

2.1.1.1 Risk Characterization

The risk characterization section summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk at the Site. Baseline risks are those risks and hazards that the Site poses if no action were taken. **Table 4 and Table 5**, risk characterization summaries, show the detailed calculation for both cancer and non-cancer risk. The BHHRA organized the types of risk at the Site according to various exposure scenarios. Each exposure scenario specifies the type of human receptor (e.g., child resident, adult industrial worker), the exposure pathway (e.g., inhalation, ingestion), and the COC. If a contaminant or exposure scenario is found to produce a risk which will require a remedial action (based on either the carcinogenic risk or the HI) that contaminant or exposure scenario is said to "drive the risk" or "drive" the need for action. A remediation goal is set for site-related contaminants that drive risk. All carcinogenic risks are based on Reasonable Maximum Exposure or RME.

Carcinogens

For carcinogens, risks are generally expressed as the incremental probability of an individual's developing cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation:

Risk = CDI x SF

where:

Risk = a unitless probability (e.g., $2x10^{-5}$) of an individual's developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
SF = slope factor, expressed as $(mg/kg\text{-}day)^{-1}$.

An excess lifetime cancer risk of $1x10^{-6}$ indicates that an individual experiencing the reasonable maximum exposure estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime cancer risk" because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. The chance of an individual's developing cancer from all other causes has been estimated to be as high as one in three. EPA's generally acceptable risk range for site-related exposures is $1x10^{-4}$ to $1x10^{-6}$.

Noncarcinogens

The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., life-time) with a RfD derived for a similar exposure period. The ratio of exposure to toxicity is called a hazard quotient (HQ). A HQ less than 1 indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic noncarcinogenic effects from that chemical are unlikely. The Hazard Index (HI) is generated by adding the HQs for all chemical(s) of concern that affect the same target organ (e.g., liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. A HI less than 1 indicates that, based on the sum of all HQ's from different contaminants and exposure routes, toxic noncarcinogenic effects from all contaminants are unlikely. A HI greater than 1 indicates that site-related exposures may present a risk to human health.

The HQ is calculated as follows:

Non-cancer HQ = CDI/RfD

where:
CDI = Chronic daily intake
RfD = reference dose.

CDI and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or short-term).

Risk characterization involves estimating the magnitude of the potential adverse health effects under study. This was accomplished by combining the results of the toxicity assessments and exposure assessments to provide numerical estimates of potential health effects. These values represent comparisons of exposure levels with appropriate toxicity threshold values and estimates of excess cancer risk. Risk characterization also considers the nature of and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding such estimates. Although the risk assessment produces numerical estimates of risk, these numbers do not predict actual health outcomes. The estimates are calculated to overestimate risk, and thus any actual risks are likely to be lower than these estimates, and may even be zero.

Generally, EPA considers remedial action to be warranted at a site where the ELCR exceeds 1 x 10^{-4}. The need for action for risks falling within the 1 x 10^{-4} to 1 x 10^{-6} range is judged on a case-by-case basis (unless applicable or relevant and appropriate requirements are exceeded). Risks less than 1 x 10^{-6} generally do not require remedial action. The point of departure for evaluating ELCR (individual carcinogens) is 1 x 10^{-6}. A hazard quotient or hazard index greater than one indicates some potential for adverse non-cancer health effects associated with COCs (EPA, 1991).

Risk characterization is the integration of the exposure and toxicity information to make quantitative estimates and/or qualitative statements regarding potential risk to human health. This section describes the risk characterization process for carcinogenic and noncarcinogenic PCOCs.

The BHHRA evaluated site-specific exposures based on realistic current and possible future land use. Table 27 provides a summary of the HIs for each scenario using average and RME assumptions for the soil pathways. None of the HIs for the soil exposure pathways exceeded EPA's target hazard index of 1. Exposure from the vapor intrusion pathway from PCOCs in groundwater for a hypothetical industrial worker employed in a building sited at the North Area resulted in an HI greater than 1, as shown in Table 26. Detailed spreadsheets containing the risk calculations are provided in Appendix D by scenario.

It should be noted that due to lead's unique toxicological properties, noncancer risk estimates could not be calculated similarly to the other noncarcinogenic PCOCs. However, none of the measured concentrations of lead in Site soil exceeded EPA's screening level for industrial properties of 800 mg/kg (EPA, 2004a). Thus, it is unlikely that lead at the Site poses an unacceptable risk.

CONTACT RECREATION SCENARIO

Exposure to sediment and surface water by the youth trespasser and contact recreation receptor were evaluated using TCEQ contact recreation PCLs for these media. None of the PCOCs detected in these media exceeded their respective PCLs (see Tables 4, 5, 6, 7, 11, 12, 13, and 14). As such, exposure to PCOCs in these media is unlikely to result in an adverse health risk.

OFF-SITE RESIDENTIAL SCENARIO

Off-site residential receptor risks were estimated by comparing PCOC concentrations in on-Site soil samples to their respective TCEQ's PCLs that were developed to evaluate exposure to air emissions from particulate dust and VOCs emitted from contaminated soil. This approach is conservative since diluting effects of off-site migration and dispersion were not considered. Even so, unacceptable risks are not expected since none of the compounds measured in South Area soils exceeded the screening criteria (see Tables 23 and 24).

FUTURE ON-SITE INDUSTRIAL WORKER VAPOR INTRUSION PATHWAY RISK ESTIMATES

The average groundwater concentration and RME EPC established for each compound at the South and North Areas was entered into the J&E VIM to determine the "Incremental Risk from Vapor Intrusion to Indoor Air, Carcinogen (unitless)" and "Hazard Quotient from Vapor Intrusion to Indoor Air, Noncarcinogen (unitless)". The results of this evaluation are presented in Tables 25 and 26 for the North Area and South Area, respectively, and suggest that, under the conservative assumptions of the J&E VIM, a potential unacceptable risk is likely at the North Area in the event that a building is constructed over the Zone A groundwater plume and vapor intrusion occurs similar to the model's predictions. As noted

previously, this conservative evaluation does not consider the restrictive covenants for Lots 55, 56, and 57 that require building design to exclude vapor intrusion.

3.0 UNCERTAINTY ASSESSMENT

Uncertainties are inherent in every aspect of a quantitative risk assessment. The inclusion of site-specific factors can decrease uncertainty, although significant uncertainty persists in even the most site-specific risk assessments. Worst-case assumptions and default values, which conform to EPA guidance (EPA, 1989), add conservatism to human health risk assessments. This conservatism is intentionally included in order to tilt the assessment toward over-prediction of risk and hence protection of human health. It is important to the risk management decision-making process that the sources of uncertainty are provided. Therefore, sources of uncertainty in the identification of PCOCs, exposure assessment, and toxicity assessment sections of the risk assessment report are identified and qualitatively evaluated in this section.

DATA ANALYSIS UNCERTAINTIES

Data collected at the Site satisfied the goals described in the Work Plan (PBW, 2006a) and, thus, adequately characterized the nature and extent of contamination at this Site. As described in the NEDR (PBW, 2009), hundreds of samples of soil, sediment, groundwater and surface water were collected at the South Area, North Area, Intracoastal Waterway, and background soil, sediment, and surface water locations. Characterization was initially conducted for the entire Site and continued at certain areas if a screening level was exceeded.

Overall, the data were determined to be of high quality. Data were collected and analyzed in accordance with approved procedures specified in the FSP (PBW, 2006b) and were validated in accordance with approved validation procedures specified in the QAPP (PBW, 2006c). Very few of the data for any of the analytes were found to be unusable (i.e., "R-flagged"). In instances where data were unusable, the analysis was conducted again (when possible) and the R-flagged data was not used. Some of the data are qualified (i.e., "J-flagged") as estimated because the measured concentration is above the sample detection limit but below the sample quantitation limit and/or due to minor quality control deficiencies. According to the *Guidance for Data Useability in Risk Assessment (Part A)* (EPA, 1992b), data that are qualified as estimated can be used for risk assessment purposes. Data quality was discussed in greater detail in the NEDR (PBW, 2009).

EXPOSURE ANALYSIS UNCERTAINTIES

The RAGS (EPA, 1989) risk assessment approach to exposure assessments generally requires standard hypothetical exposure scenarios rather than realistic site-specific evaluation of exposure, and this conservative default approach was used for the future industrial and construction worker scenarios. Under this approach, if a chemical is found to be present at a site, it is assumed that exposure to that chemical will occur regardless of whether that exposure is realistic or likely. Uncertainties associated with the exposure assessment included calculation of EPCs and selection of exposure parameters. For example, the intake equations are based on several 95^{th} percentile values. When multiplied together, these data compound the uncertainties in the exposure assessments and result in estimated intakes (and resultant cancer risks) that likely estimate exposure well over the 95^{th} percentile.

It is difficult to assess the likelihood of any of the hypothetical future scenarios occurring (i.e., future construction worker or future industrial worker) nor is it possible to know the extent, if any, that trespassers and contact recreation receptors are exposed to PCOCs at the Site. It was assumed that the youth trespasser accesses the Site once a week for twelve years. It was assumed that the contact recreation scenario receptor visits the Site for 39 times per year for 25 years. The exposure assumptions used for all scenarios were chosen to purposefully overestimate exposure in order to err on the side of protection. For the current scenarios (i.e., the youth trespasser and the contact recreation scenario) it appears that these represent a bounding estimate since exposure is likely to be much less.

The screening conducted to evaluate off-site impacts from particulate dust generation and VOC emissions and migration was very conservative because it did not assume any dispersion during transport. Despite that very conservative assumption, no adverse risks to off-site residents were likely.

Soil ingestion rates for adults and older youth are highly uncertain. Because the ingestion rate is a very sensitive parameter in the intake equation, uncertainty and variability in this assumption has a large impact on the dose estimate. This is especially relevant for the construction worker scenario when an enhanced ingestion rate was used. The uncertainty related to this value is tremendous given the study design, small study population, and limited exposure length that are the basis for the soil ingestion rate.

Assumptions regarding bioavailability of metals in soil can significantly influence risk estimates. EPA typically assumes that the bioavailability of compounds from soil is equal to that observed in the toxicity studies used to derive oral toxicity factors but this is most often not the case. Rather, toxicity studies are often, if not always, conducted using a concentration of a compound in either food or water. Bioavailability was assumed to be 100% (i.e., AAF was 1.0) although it is well known that metals and some organic compounds bound to soil are less than 100% bioavailable. This assumption leads to an overestimation of risks, which can be significant.

For surface water, groundwater, and sediment in the ponds, maximum concentrations were selected as the EPC for purposes of evaluating human health risks. This is likely to be a conservative approach since there were other, lower concentrations, also measured for these media.

TOXICITY ASSESSMENT UNCERTAINTIES

The studies/basis for the toxicity information and the use of this information generate uncertainty. Toxicity assessments for many of the PCOCs in the BHHRA involve the extrapolation of results from studies on animals. The following are standard assumptions applied by the EPA when extrapolating the results of studies of carcinogenicity in animals to humans.

- Any constituent showing carcinogenic activity in any animal species will also be a human carcinogen.
- There is no threshold dose for carcinogens.
- The results of the most sensitive animal study are appropriate to apply to humans.
- Humans are more sensitive than the most sensitive animal species on a body weight basis.

Uncertainties are introduced in animal to human extrapolation and high to low dose extrapolation. Mathematical models are used by EPA to estimate the possible responses due to exposure to chemicals at levels far below those tested in animals. These models contain several limitations, which should be considered when the results (e.g., risk estimates) are evaluated. Primary among these limitations is the uncertainty in extrapolation of results obtained in animal research to humans and the shortcomings in extrapolating responses obtained from high-dose research studies to estimate responses at very low doses. For example, humans are typically exposed to environmental chemicals at levels that are less than a

thousandth of the lowest dose tested in animals. Such doses may be easily degraded or eliminated by physiological internal mechanisms that are present in humans (Ames, 1987).

Additionally, approaches typically used for designating RfDs are highly conservative. For example, EPA (1989) applies a factor of 10 to a No-Observable-Adverse-Effect-Level (NOAEL) for a compound in an animal study for animal-to-human extrapolation. An additional factor of 10 is applied for inter-individual variation in the human population, and additional factors of 10 may be applied to account for limitations in data quality or incomplete studies. Frequently, RfDs are derived from animal studies that have little quantitative bearing on potential adverse effects in humans. Some of this uncertainty may be reduced if the absorption, distribution, metabolic fate, and excretion parameters of a compound are known.

Potential long-term, or chronic, exposures are typically evaluated in risk assessments for Superfund sites, and chronic RfDs and RfCs are the appropriate toxicity criteria to apply to chronic exposure scenarios (chronic exposure is defined in EPA, 1989 as greater than or equal to seven years). The BHHRA includes a construction worker scenario, which was assumed to be of a shorter duration than seven years and is, therefore, considered a subchronic exposure scenario. In some cases, EPA provides recommended subchronic RfDs which are typically 10 times higher than chronic values. Only chronic toxicity values were used in the risk assessment, which imparts conservatism in the construction worker scenario.

RISK CHARACTERIZATION UNCERTAINTIES

The only instance where uncertainty may have been introduced into the risk assessment that is not considered conservative was when toxicity values or screening criteria were not available. This was only an issue when evaluating impacts to off-site receptors since there are not inhalation toxicity values for many of the compounds (or TCEQ PCLs) and, as such, a comparison could not be made. It is believed that this is insignificant since: 1) there are few VOCs present in soil at the South Area; 2) the VOCs that are present were measured in low concentrations; and 3) surficial soil testing for lead on Lots 19 and 20 did not suggest that off-site migration via fugitive dust generation was a significant concern.

It was estimated that risks associated with VOC emissions from shallow Zone A groundwater to future inhabitants of buildings were above EPA's target risk goals. It should be noted that this is a highly uncertain pathway with the use of many default assumptions to calculate risks since currently the pathway is incomplete (i.e., there is no building or no worker at the Site 250 days per year for exposure to occur).

Likewise, conservative assumptions were made about the slab and slab integrity and contaminant transport in the J&E VIM that would greatly affect the resulting risk estimates. Therefore, it is advisable to consider the results of this analysis in light of the substantial amount of uncertainty in the underlying assumptions of this pathway.

IMPACT OF UNCERTAINTIES

As described in this section, efforts were made in the BHHRA to purposefully err on the side of conservatism in the absence of site-specific information. It is believed that the overall impact of the uncertainty and conservative nature of the evaluation results in an overly protective assessment. Therefore, for scenarios with risks and HIs within or below the Superfund risk range goal and target HI, it can be said with confidence that these environmental media and areas do not present an unacceptable risk.

4.0 CONCLUSIONS

The primary objective of this BHHRA was to evaluate the possible risks associated with PCOCs in environmental media on human receptors at the Gulfco Marine Maintenance Site. This information will be used to help guide future risk management decisions at the Site. The risk assessment methodology used to conduct this analysis was based on the approach described by EPA in various supplemental and associated guidance documents as documented throughout the report.

Data were segregated by media and by location (e.g., North Area soil and South Area soil; Intracoastal Waterway sediment and Wetlands sediment) and distribution testing was performed. Exposure point concentrations were estimated for all PCOCs for both central tendency (average) and RME (95% UCL) exposures using EPA's ProUCL program.

Five different exposure scenarios were quantitatively evaluated for the thirteen different potentially contaminated media identified at the Site. Exposure scenarios were developed to describe current and potential future land use by various human receptors and included a future industrial worker, future construction worker, current youth trespasser, current contact recreation receptor, and current off-site residential receptor. Exposure and risks were calculated for both central tendency and RME scenarios.

The risk assessment showed that there were not unacceptable cancer risk or noncancer hazard indices for any of the current or future exposure scenarios except for future exposure to an indoor industrial worker if a building is constructed over impacted groundwater in the North Area. Potential cancer risks in the North Area using maximum shallow Zone A groundwater concentrations and the J&E VIM were predicted to be greater than 1×10^{-4} while the HIs were estimated to be greater than 1. It should be noted that this scenario was evaluated despite the current restrictive covenant on Lots 55, 56, and 57 that require future building design to preclude vapor intrusion, which would effectively make this pathway incomplete. Therefore, current risks at the Site are acceptable given the low levels of potential exposure. Estimated risks from Zone A groundwater at the South Area were below EPA's goals and, therefore, adverse risks associated with the vapor intrusion pathway are unlikely in this area.